Joint Optimization of Mobile Transmission Power and SIR Error in CDMA Systems

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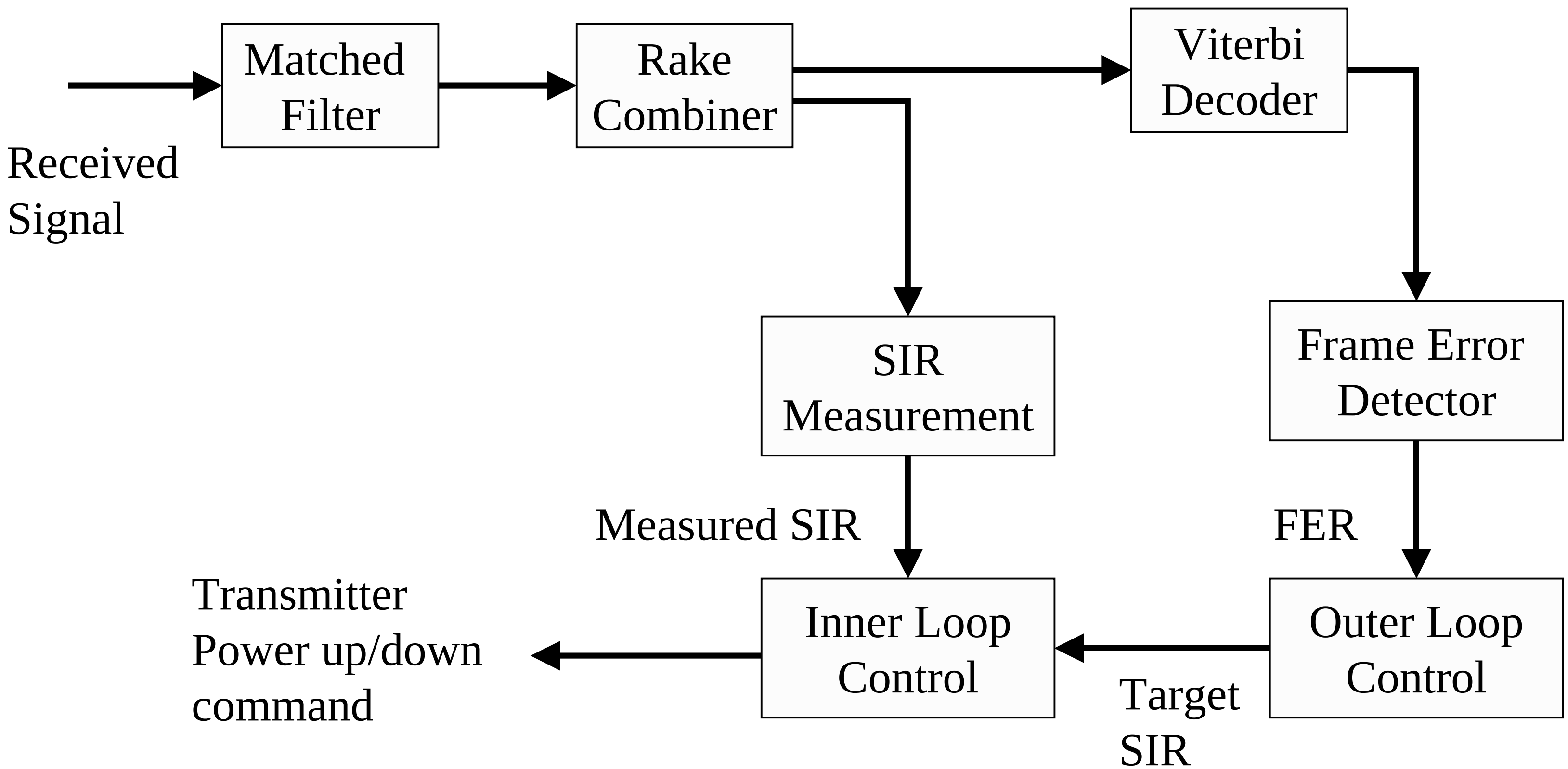
Transmitter Power Control Process



Base Station Behavior

Motivation: An Optimal Solution of the Distributed Power Control Problem

1. Save mobile's transmission power when there is tolerance on SIR error.

2. Fast convergence of power control scheme is indispensable.

3. Dynamic optimization method should be applied to get the optimal solution.

System Model

Assumptions:

1. Uplink power control in a spread spectrum system (DS-CDMA) with N active users.

2. The link gain between the mobile and its assigned base station, and the received interference at the base station can be estimated.

Definition: SIR at the base station n from mobile i

$$\gamma_{ni} = \frac{L h_{ni} p_i}{\sum_{j \neq i} h_{nj} p_j + \sigma^2}$$

L : spreading gain

p_i, p_j : trans. power

h_{ni}, h_{nj} : link gains

σ^2 : recv. noise

$$I_i(k) = \sum_{j \neq i} h_{nj}(k) p_j(k) + \sigma^2$$: interference

$$\delta_i(k) = \frac{L h_{ni}(k)}{I_i(k)}$$: measure of channel variation

- Power Increment: $\Delta p_i(k+1) = p_i(k+1) - p_i(k)$
- SIR Error: $e_i(k) = \gamma_i^{tar} - \gamma_i(k)$
- Proportional Control: $\Delta p_i(k+1) = \alpha_i(k) e_i(k)$
- Power Control Law:

$$p_i(k+1) = p_i(k) + \alpha_i(k)(\gamma_i^{tar} - \gamma_i(k))$$

$\alpha_i(k)$: Controller Gain

Joint Minimization of Error and Power

Performance Criterion: weighted combination of SIR error and mobile's transmission power.

$$J_i(k) = \min_{\alpha_i(k)} [\rho_1 e_i^2(k+1) + \rho_2 p_i^2(k+1)]$$

i=1,2,…,N.

$\rho_1, \rho_2 > 0$: weights

Subject to: $0 < p^{\min} \leq p_i(k), p_i(k+1) \leq p^{\max}$

This optimization problem can be solved by nonlinear programming.

Optimal Control of Error and Power

Case 1. When channel quality is good: $\delta_i(k+1)\,p^{\min} > \gamma_i^{tar}$

Optimal Control: $p_i(k+1) = p^{\min}$

Case 2. When channel quality is bad:

$$\frac{\rho_1 \delta_i^2(k+1) + \rho_2}{\rho_1 \delta_i(k+1)}\, p^{\max} < \gamma_i^{tar}$$

Optimal Control: $p_i(k+1) = p^{\max}$

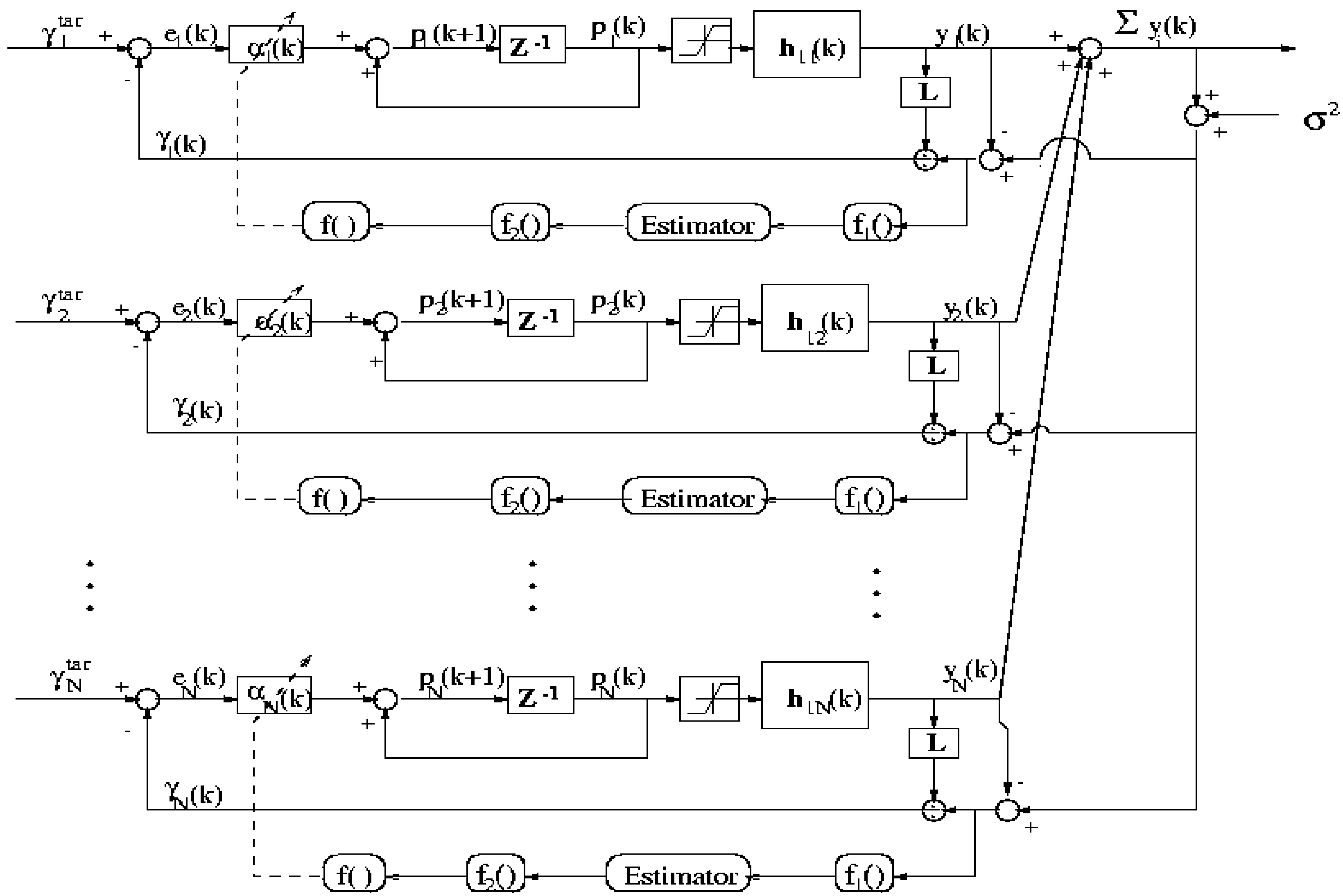
Case 3. When channel quality is normal :

Optimal Control: $$p_i(k+1) = p_i(k) + \hat{\alpha}_i(k) e_i(k)$$

Optimal controller gain:

$$\hat{\alpha}_i(k) = \begin{cases} \dfrac{1}{\hat{\delta}_i(k)}\left(1 - \dfrac{\gamma_i^{tar}}{e_i(k)}\right) + \dfrac{\rho_1 \hat{\delta}_i(k+1)}{\rho_1 \hat{\delta}_i^{\,2}(k+1) + \rho_2} \dfrac{\gamma_i^{tar}}{e_i(k)} & \text{if} \quad e_i(k) \neq 0 \\ 0 & \text{if} \quad e_i(k) = 0 \end{cases}$$

$\hat{\delta}_i(k)$ and $\hat{\delta}_i(k+1)$ are estimation and prediction of channel variations



Estimator
Estimator
Estimator

Estimator - H∞ Filter

H∞ Filter minimize the transfer function from disturbance to system output.

H∞ Filter:

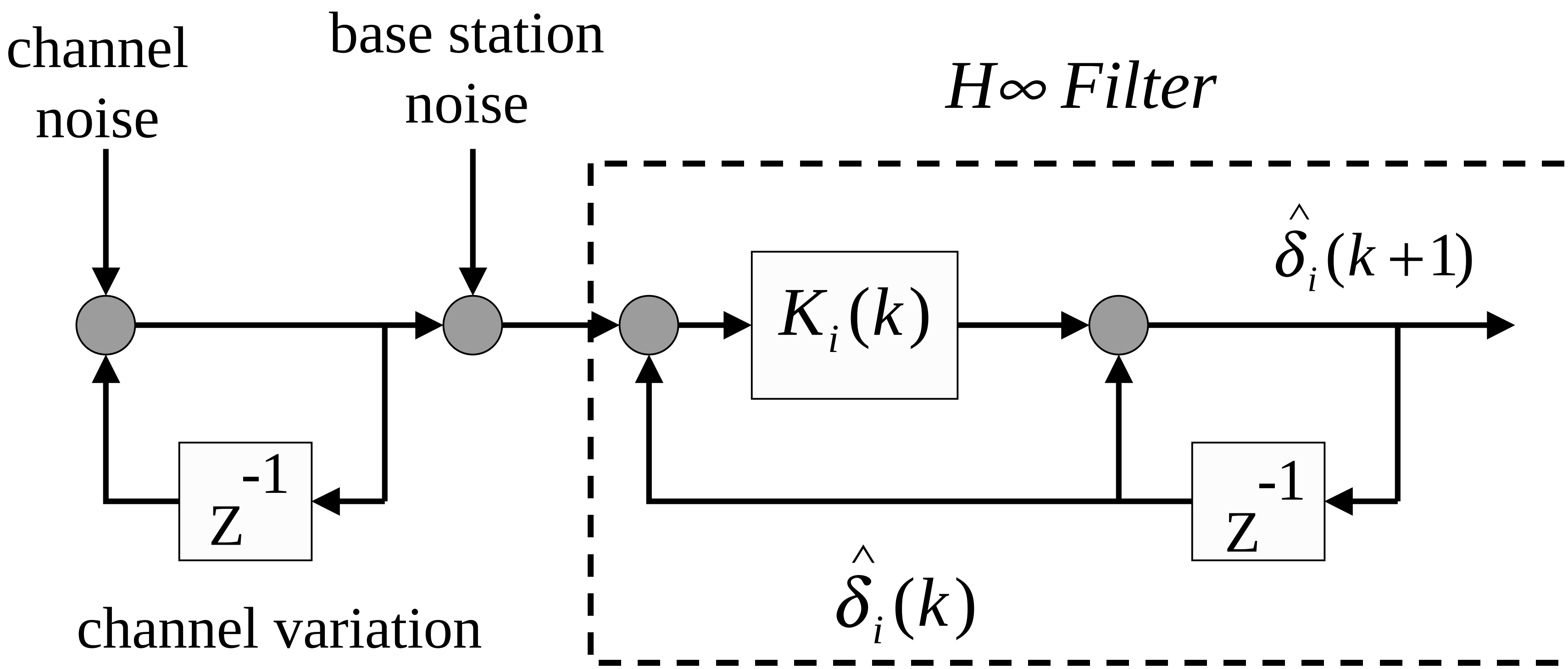
$$\hat{\delta}_i(k+1) = \hat{\delta}_i(k) + K_i(k)(y_i(k) - \hat{\delta}_i(k))$$

$K_i(k)$: filter gain

$y_i(k)$: measurement of channel variation

$\hat{\delta}_i(k)$ and $\hat{\delta}_i(k+1)$ are estimation and prediction of channel variations

Block Diagram of the H∞ Filter



$\hat{\delta}_i(k)$ and $\hat{\delta}_i(k+1)$ are estimation and prediction of channel variations

Simulations: Assumptions

1. 7 cell DS-CDMA system with 20 users in each cell.
2. The users are uniformly distributed(2-dim) in each cell.
3. Bandwidth is 1.23 MHz.
4. Data rate is 9.6 kbps.
5. Processing gain is 128 (21 dB).
6. SIR target is 7 dB, which corresponds to BER= 10^{-3}

Simulations: Assumptions Contd.

7. $p^{\min} = 8$ dBm (6.3 mW), $p^{\max} = 33$ dBm (2 W).

8. The background noise power is 0.05 mW.

9. The transmitted power is updated every 0.625 ms.

10. Link gain: $h_{ni}(k) = d_{ni}^{-4}(k) A_{ni}(k)$

$A_{ni}(k)$: lognormal

11. The standard deviation of $A_{ni}(k)$ is 8db.

Some Existing Power Control Algorithm

Distributed Balancing (DB) :

$$p(k+1) = \beta(1 + \frac{1}{\gamma(k)})\, p(k)$$

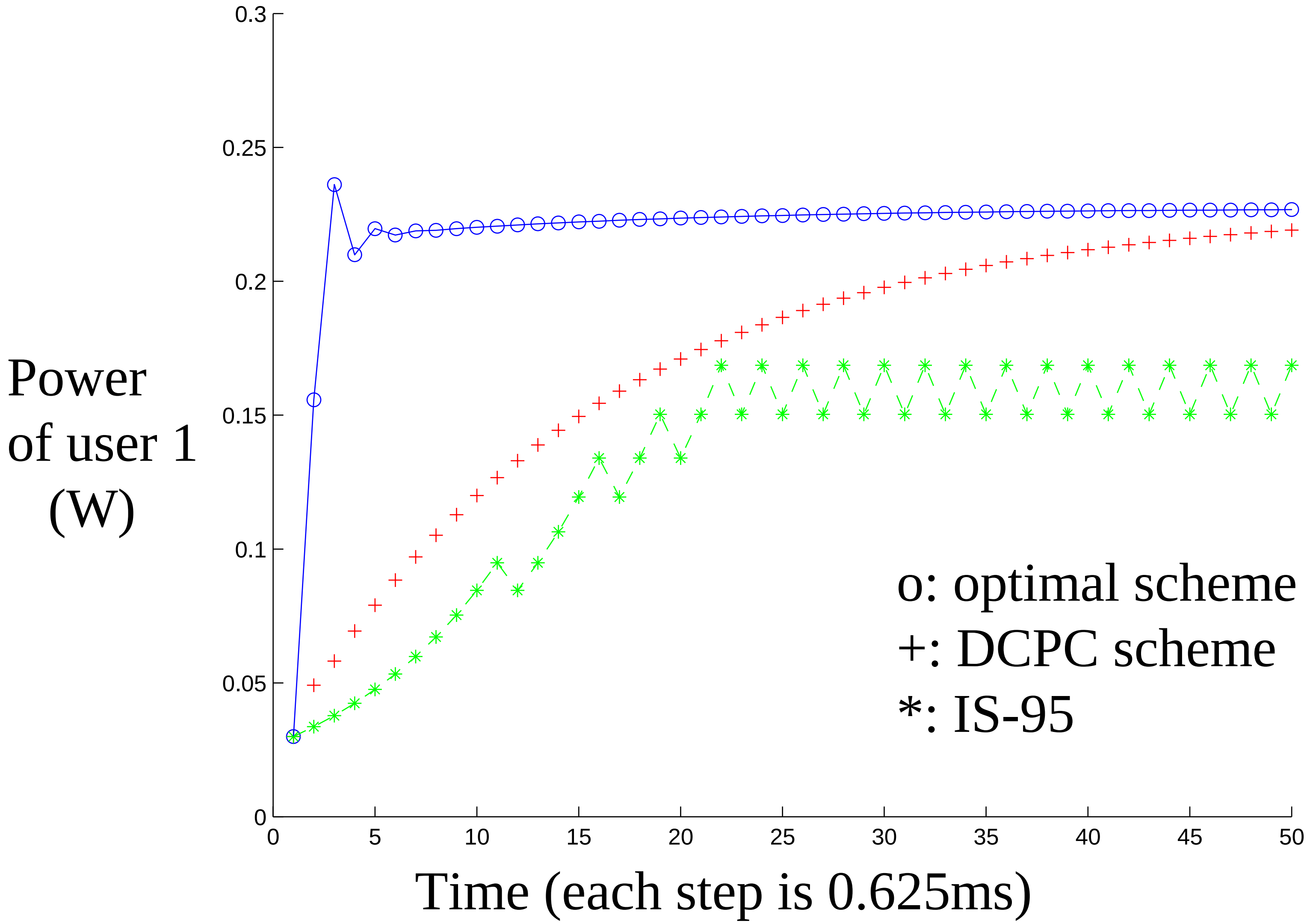
Distributed Power Control (DPC) :

$$p(k+1) = \beta\, \frac{p(k)}{\gamma(k)}$$

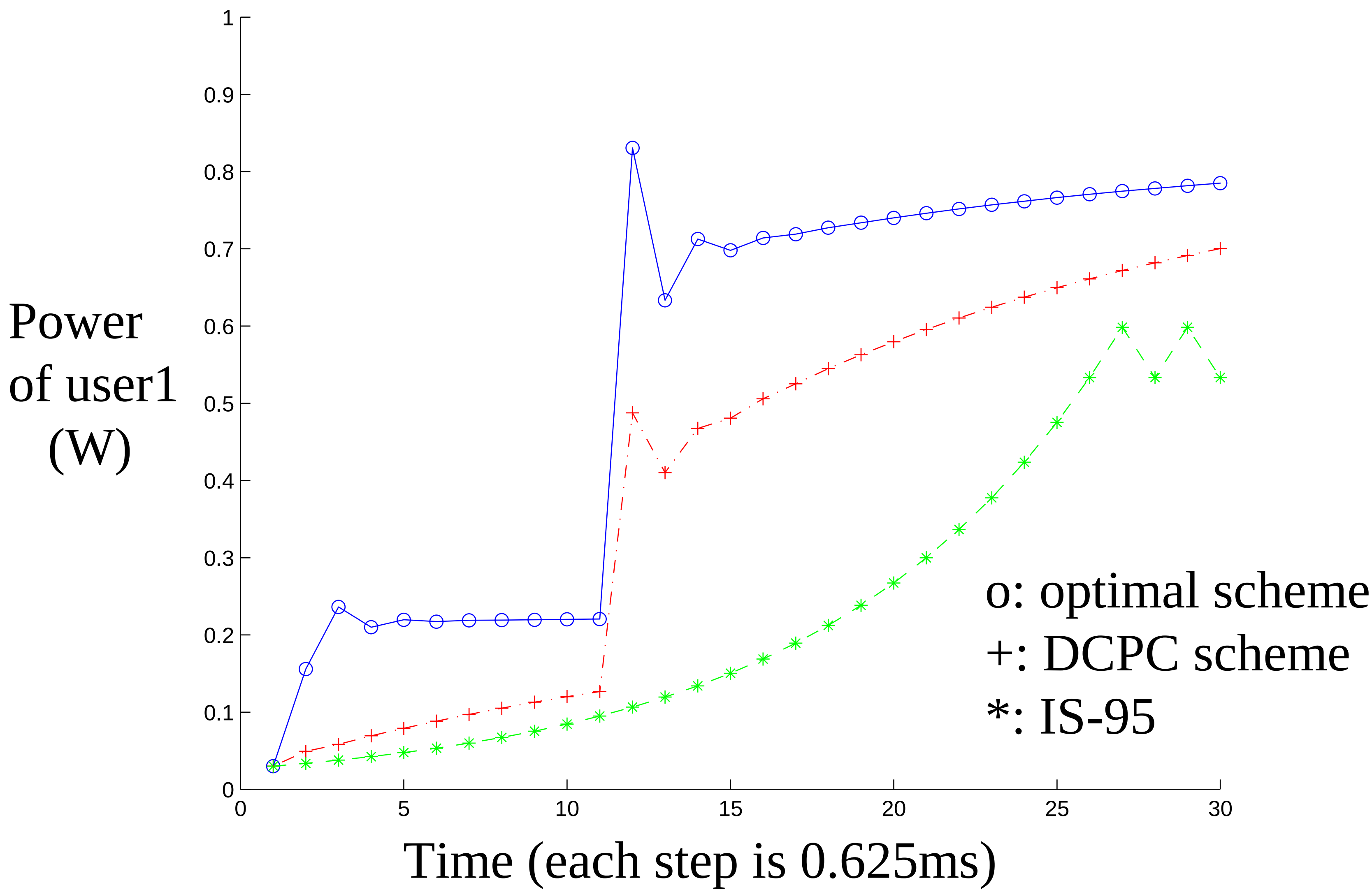
Distributed Constrained Power Control (DCPC) :

$$p(k+1) = \min(\frac{\gamma^{tar}}{\gamma(k)}\, p(k),\, p^{\max})$$

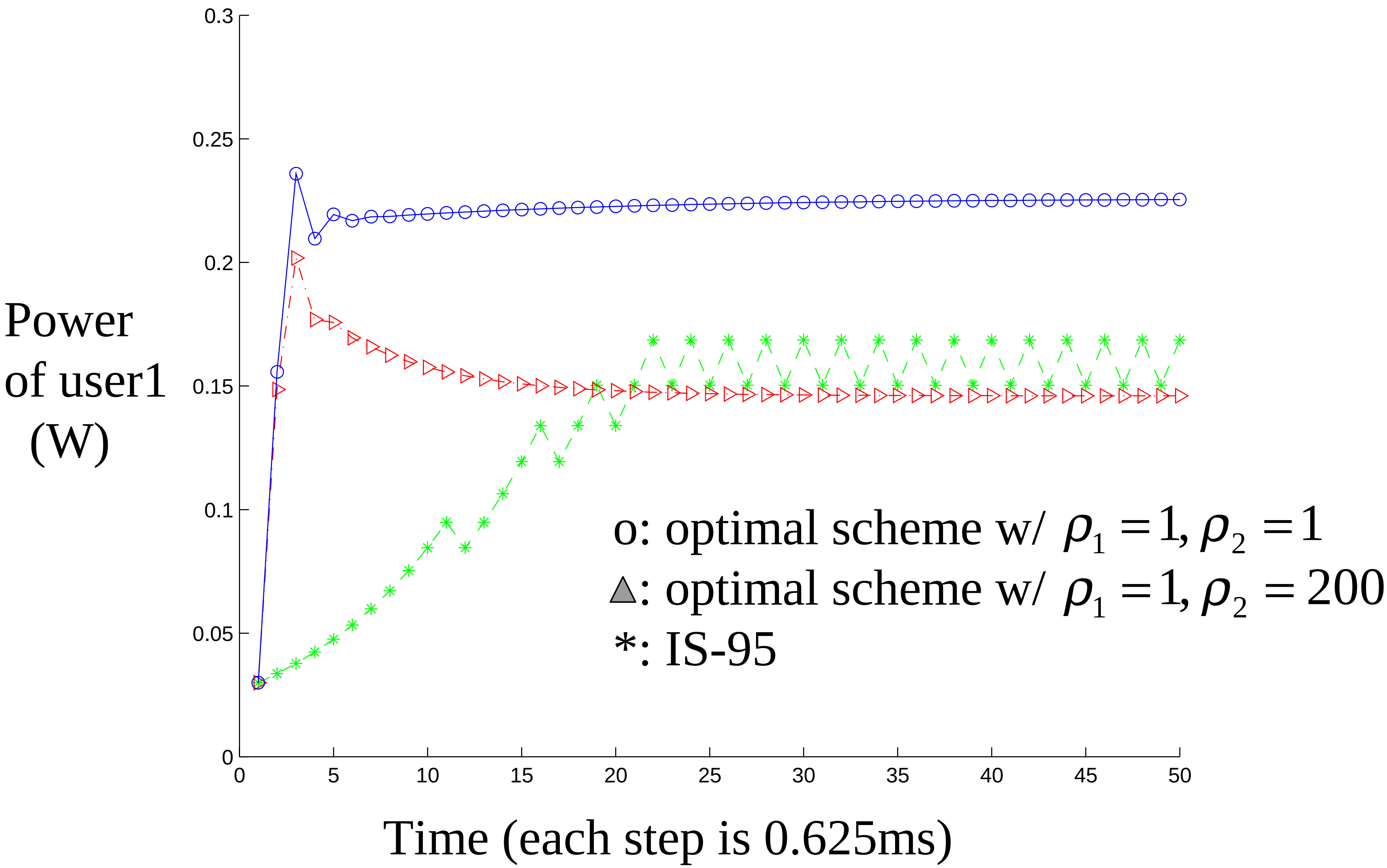
Comparison of Convergence Speed



Fast Convergence of Optimal Scheme



Joint Minimization of SIR error and Power



Conclusions and Future Work

1. Joint optimization of mobile’s transmission power and SIR error.

2. Fast convergence. The convergence takes 4-5 steps.

3. Estimator based control scheme, which adapt to channel variation.

4. Extend the work to stochastic case.